

PATENT ABSTRACTS OF JAPAN

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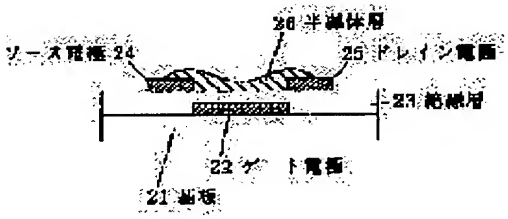
HOTTA OSAMU

(54) FIELD-EFFECT TRANSISTOR

(57)Abstract:
PURPOSE: To set a field-effect transistor equal to or higher than amorphous silicon in mobility by a method wherein a channel section is formed of organic semiconductor material, and a gate insulating layer is formed of insulating polymer having cyano groups.

CONSTITUTION: A gate electrode 22 and a gate insulating layer 23 which includes insulating polymer having cyano groups are successively formed on a substrate 21, and a source electrode 24 and a drain electrode 25 are formed thereon. An organic semiconductor layer 26 is provided so as to bridge a gap between the source electrode 24 and the drain electrode coming into contact with the gate insulating layer 23. At this point, a metal electrode, an ITO electrode or a high-doped conductive polymer electrode is used as the gate electrode 22. Polyacrylonitrile or cyanoethyl purlan is mainly used as polymer having cyano groups. The above organic semiconductor is formed of dimethyl-sexithyophene, quartathyophene, and lead phthalocyanine.



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[Patent number]

[Date of registration]

* NOTICES *

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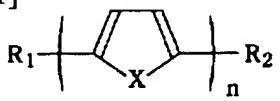
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

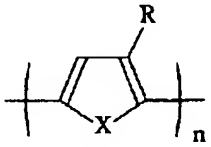
CLAIMS

[Claim(s)]
[Claim 1] The field-effect transistor which has a gate electrode, a source electrode, a drain electrode, the channel section that consisted of organic-semiconductor ingredients, and the gate insulating layer which consisted of insulating polymers which have a cyano group.
[Claim 2] An organic-semiconductor ingredient is a field-effect transistor according to claim 1 using a multi-conjugation organic compound including at least seven pi electron conjugated bonds.
[Claim 3] An organic-semiconductor ingredient is a field-effect transistor according to claim 1 or 2 using the compound shown by either of (** 6) from the following chemical formulas (** 1).
[Formula 1]



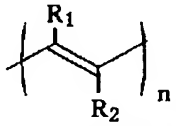
ただし、XはS，Se，Te，NH
R_1，R_2はH，アルキル基、アリール基、ハロゲン
nは正の整数

[Formula 2]



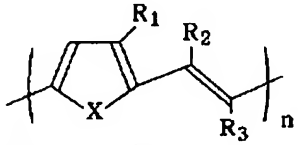
ただし、XはS，Se，Te，NH
RはH，アルキル基、アリール基、ハロゲン
nは正の整数

[Formula 3]



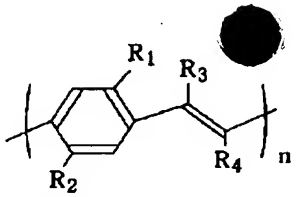
ただし、R_1，R_2はH，アルキル基、アリール基、ハロゲン
nは正の整数

[Formula 4]



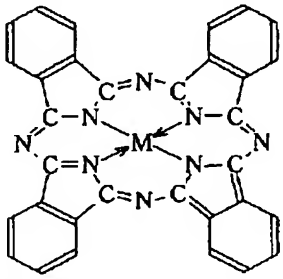
ただし、XはS，Se，Te，NH
R_1，R_2，R_3はH，アルキル基、アリール基、ハロゲン
nは正の整数

[Formula 5]



ただし、R_1, R_2, R_3, R_4 はH，アルキル基、アリール基、ハロゲン
n は正の整数

[Formula 6]



ただし、M は2価の金属

[Claim 4] For an organic-semiconductor ingredient, claims 1-3 which are the compounds with which the pi electron conjugated system shown with the following chemical formulas (** 7) spread are the field-effect transistors of a publication either.

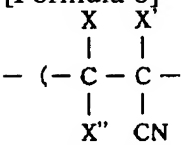
[Formula 7]

$R-(C_4H_2S)_n-R'$

ただしR，R'はH，アルキル基、ハロゲン、フェニル基

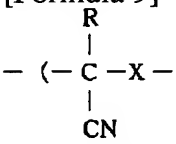
[Claim 5] For the insulating polymer which has a cyano group, claims 1-4 using the compound shown by either of (** 11) from the following chemical formulas (** 8) are the field-effect transistors of a publication either.

[Formula 8]



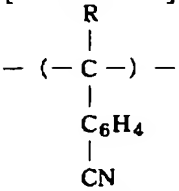
ただしX，X'，X"はH，アルキル基、フェニル基、ハロゲン

[Formula 9]



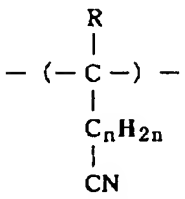
ただしXはO，S，S_e，CH_2，$-C_6H_4-$
RはH，アルキル基、ハロゲン、フェニル基

[Formula 10]



ただしRはH，アルキル基、ハロゲン、フェニル基

[Formula 11]



ただしRはH，アルキル基、ハロゲン、フェニル基
nは正の整数

[Claim 6] For the insulating polymer which has a cyano group, claims 1-5 which are polyacrylonitriles are the field-effect transistors of a publication either.
[Claim 7] A field-effect transistor given in six from claim 1 to which the insulating polymer which a gate insulating layer is the bipolar membrane which consists of an insulating polymer which has silicon oxide and a cyano group, and has a cyano group touches the channel section.

[Translation done.]

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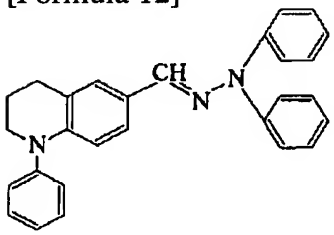
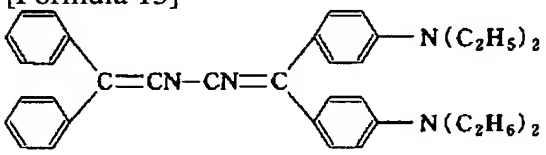
DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] Especially this invention relates to the field-effect transistor which used the organic-semiconductor ingredient for the channel layer about a field-effect transistor.
[0002]
[Description of the Prior Art] In recent years, the field-effect transistor (FET) which used the organic semiconductor for the channel part can obtain a large area easily, and is expected as objects for actuation, such as a display.
[0003] What is shown in this organic semiconductor below is reported typically. For example, the poly thiophene (applied physics Letters: indicate to A.Tsumura et al., Appl.Phys.Lett., 49 volumes, and 1210 pages (1986)), Polypyrrole, poly thienylene vinylene (the "53rd application physics scientific lecture meeting 18 besides Fuchigami pZ12 (1992) publication), The ingredient which fully dedoped conductive polymers, such as polyphenylene vinylene, The conductive polymer into which qualification radicals, such as an alkyl group or a methoxy group, were introduced for fusibility, The oligomer ingredient with which pi conjugated system, such as an oligo thiophene (it indicates to JP,4-133351,A), spread, Phthalocyanines (it indicates to JP,1-155658,A), a nickel phthalocyanine (chemical physics Letters: indicate to G.Guillaud, J.Simon, Chem.Phys.Lett.219 volume, and 123 pages (1994)), The substitution product of a silicon phthalocyanine (Singh solid films magazine: indicate to Y.L.Hua et al., Thin Solid Films, 192 volumes, and 383 pages (1990)), RUTESHIUMU About JIFUTARO cyanine, chemical physics Letters M. Madru, et It will indicate in al., Chem.Phys.Lett., 142 volumes, 103 pages, and (1987). condensation pi conjugated compound (the "52nd Japan Society of Applied Physics scientific lecture meeting" besides Waratani --), such as tetracene pentacene It is BEDT-TTF (it indicates to "52nd Japan Society of Applied Physics scientific lecture meeting" 9pR9 (1991) besides Waratani) which is the donor nature child a publication and its charge transfer mold complex indicate superconduction to be to 9pR(s)9 (1991) for a while, and is various.
[0004] Moreover, many attempts are made in order to raise a field-effect transistor property.
[0005] For example, the crystallinity of the thin film of an organic-semiconductor ingredient is raised [using the organic-semiconductor ingredient with which pi conjugated system fully spread,], Donor nature is raised by introducing a methyl group into an organic-semiconductor ingredient, and the property as a semi-conductor of p mold is raised, By using not an organic semiconductor with dispersion in polymerization degree but the organic-semiconductor ingredient of the oligomer of single polymerization degree etc., improvement in the mobility of the carrier which is the important parameter which opts for the engine performance of a field-effect transistor is aimed at.
[0006] The field-effect transistor (it indicates to JP,4-133351,A) using a dimethyl oligo thiophene without a molecular weight distribution is one of such the attempts.
[0007] Or the attempt which the conversion efficiency from the precursor of poly thienylene vinylene is gathered, and polymerization degree is raised, and obtains improvement in mobility is also made, and the mobility of 0.2cm2/Vs is obtained (it indicates to "53rd application physics scientific lecture meeting" 18pZ12 (1992) besides Fuchigami).
[0008] Moreover, using for a field-effect transistor the oligo thiophene of the degrees of polymerization 3, 4, and 5 which permuted both ends by the methyl group or the ethyl group as an organic semiconductor is also indicated (it indicates to JP,4-133351,A).

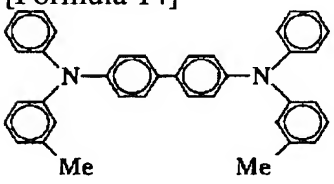
[0009] Moreover, if the high organic semiconductor of donor nature, i.e., the small organic semiconductor of ionization potential, is used for a channel layer, it is reported to ****** "collection of creation science propulsion business [in the 1991 fiscal year] research report meeting summaries" Research Development Corp. of Japan (1991) that high electric-field mobility can be obtained, and it is shown that introducing a radical with donor nature, such as developing pi conjugated system and a methyl group, leads to improvement in mobility.
[0010] Moreover, a field-effect transistor is produced also about some hole transport ingredients, and the mobility is called for.
[0011] Incidentally, the level of HOMO (highest occupied molecular orbital) is the ingredient with which a shallow organic-semiconductor ingredient, i.e., electron-donative, has a hole transport ingredient small [ionization potential], and thoria reel amines, aromatic series hydrazones, aromatic substitution pyrazolines, and stilbenes are known.
[0012] Therefore, a hole will be easy to be produced also by impressing gate voltage with field-effect transistor structure.
[0013] If an example is given, the mobility of 1.8x10-8cm2/Vs is obtained by 1 shown with the following chemical formulas (** 12), 1-bis(p-diethyl aminophenyl)-4, 4-diphenyl-1, 3-butadiene, and (the CAS registration number 109995-82-6 and molecular formula C28H25N3).
[0014]
[Formula 12]



[0015] Moreover, the mobility of 2.7x10-6cm2/Vs is obtained by 1-phenyl-1 shown with the following chemical formulas (** 13), 2 and 3, 4-tetrahydroquinolin-6-carboxaldehyde-1', 1'-diphenylhydrazone, and (the CAS registration number 100070-43-7 and molecular formula C36H40N2).
[0016]
[Formula 13]

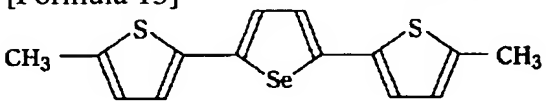


[0017] Moreover, a field-effect transistor is made also from N shown with the following chemical formulas (** 14), N'-dipheynyl-N, N'-bis(3-methylphenyl)-1, 1'-biphenyl-4, 4'-diamine, and the (CAS registration number 65181-78-4 called TPD), and mobility is measured.
[0018]
[Formula 14]



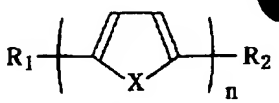
[0019] In addition, it is known like [selenium ********** seleno FEN] oligo thiophenes in the sulfur atom of a thiophene ring that actuation of a field-effect transistor is shown.
[0020] Moreover, the field-effect transistor is operating also by the molecular structure shown with the chemical formula (** 15) of the following which transposed the sulfur atom of the thiophene ring of the center of a JIMECHIRUTA thiophene to the selenium.
[0021]

[Formula 15]



[0022] As for this, the molecule which transposed the sulfur atom of a thiophene ring to the selenium and the tellurium atom also shows that a field-effect transistor operates similarly.
[0023] now, as an advantage of the field-effect transistor which used the organic semiconductor for the channel layer A large area can be made from a simple process by the spin coat, electrolytic polymerization, etc., The organic semiconductor of many OK even if it bends with soft structure unlike an inorganic semi-conductor has susceptibility to gas, and can use as a sensor, Having the merit of the affinity of combination, since many of it being able to design out of a variety and various ingredients because there are also many from which a frame's differs and an organic semiconductor's moreover changes a qualification radical, and things an organic-semiconductor ingredient indicates fluorescence to be also become the ingredient of light emitting diode (LED) etc. is raised.
[0024] For example, LED which made the dimethyl sexy thiophene the luminous layer is also produced (sakaki the Uchiyama **********, the Hotta **********, Hiroyuki, the 54th Japan Society of Applied Physics scientific lecture meeting (1993), 29 p-ZC -1).
[0025] Of course, in order to demonstrate these advantages, it will be the requisite that sufficient mobility of an organic semiconductor is securable.
[0026] Moreover, Garnier etc. is producing the field-effect transistor whose gate insulating layer and channel layer are the organic substance (advanced MATERIARUZU: F.Garnier, G.Horowitz, X.Peng, D.Fichou, Adv.Mater., two volumes, 592 pages (1990)).
[0027] Here, since the thing with the electric capacity large in order to take the large drain current of a field-effect transistor per unit area of a gate insulating layer is good, the high insulating polymer of a high dielectric constant is used for the gate insulating layer.
[0028] Moreover, it is reported that the mobility of the organic semiconductor of the channel layer measured with field-effect transistor structure changes with the construction material of a gate insulating layer.
[0029] For example, it has reported that Garnier etc. uses a cyano ethyl pullulan for a gate insulating layer, and its mobility of the vacuum evaporationo film of a sexy thiophene improves (advanced MATERIARUZU: F.Garnier, G.Horowitz, X.Peng, D.Fichou, Adv.Mater., two volumes, 592 pages (1990)). In addition, there is the same publication also as the Patent Publication Heisei No. 508745 [five to] official report.
[0030] The alpha position of the thiophene ring of an end is the oligo thiophene of the hexamer which is not permuted [which is a hydrogen atom], and the sexy thiophene used here is surmising that that the specific inductive capacity of a cyano ethyl pullulan is as high as epsilon= 18.5 (with 10kHz) has caused improvement in the mobility of the organic semiconductor near the interface.
[0031] In addition, since a cyano ethyl pullulan melts into solvents, such as an acetone, easily in spite of such efforts, after producing a cyano ethyl pullulan, there is demerit in which organic washing or lithography (these are indispensable conditions when using the field-effect transistor which used the organic semiconductor for the channel layer as a thin film transistor for liquid crystal display device actuation.) cannot be used at all, and it has been a decisive failure when it is going to make a field-effect transistor from high density.
[0032] and which conventional example -- also setting -- the mobility of an organic-semiconductor thin film -- an amorphous silicon and an EQC -- or it is important technical problems to become more than it and to raise the resistance to environment of a component in addition to it.
[0033] Below, the field-effect transistor which used the conventional organic semiconductor for the channel layer is explained.
[0034] Drawing 2 is the sectional view showing the example of a configuration of the field-effect transistor which used the organic semiconductor for the channel layer.
[0035] As for the insulator with which 21 becomes a substrate, and 22, as for a gate electrode and 23, in drawing 2 , a gate insulating layer and 24 are organic-semiconductor layers from which a source electrode and 25 become a drain electrode and 26 becomes a channel.
[0036] Drawing 3 is the sectional view showing the example of a configuration of the field-effect transistor which used the conductive substrate as the gate electrode.

[0037] In drawing 3 , the organic-semiconductor layer from which in a gate insulating layer and 34 a source electrode and 35 become a drain electrode and 36 becomes [33] a channel, and 37 are gate [a substrate-cum-] electrodes, and using the silicon substrate which carried out the high concentration dope as a gate electrode hits in this case.
[0038] Drawing 4 shows the component structure which has an organic semiconductor in a substrate side rather than a gate electrode. In drawing 4 , the insulator with which 41 becomes a substrate, and 42 are the configurations a gate insulating layer and 44 are organic-semiconductor layers from which a source electrode and 45 become a drain electrode and 46 becomes a channel, and the source electrode 44 and the drain electrode 45 are on a substrate 41, they have the organic-semiconductor layer 46, and a gate electrode and 43 carried out [configurations] the laminating to the gate insulating layer 43 and the gate electrode 42 on it.
[0039] With such conventional component structure, silicon oxide, a silicon nitride film, the cyano ethyl pullulan film, the polyvinyl alcohol film, the polyvinyl chloride film, the polymethylmethacrylate (PMMA) film, and the polystyrene film are used as a gate insulating layer, and the example below a cyano ethyl pullulan is indicated in applied physics Letters (Peng et al., Appl.Phys.Lett., 57 volumes, 2013 pages (1990)) or the Patent Publication Heisei No. 508745 [five to] official report.
[0040] The actuation is explained about the field-effect transistor constituted as mentioned above.
[0041] The gate insulating-layer 23 grade inserted into the gate electrode 22 grade, the source electrode 24 grade, the drain electrode 25 grade, and the channel partial 26 grade produces a charge on both sides with the impressed electrical potential difference like a capacitor.
[0042] With the electrical potential difference of a source drain, the carrier in which induction was carried out by gate voltage into the organic-semiconductor 26 grade serves as a drain current, and flows.
[0043] Here, if an organic semiconductor is p mold, an electron hole (hole) will be excited, and an electron will be excited if it is n mold.
[0044] In addition, in order to reduce the drain current in gate voltage VG=0, as for an organic-semiconductor thin film, it is common that dedoping the impurity of the thin film which vapor-deposited the ingredient with which the impurity was fully pressed down, or was generated is made.
[0045]
[Problem(s) to be Solved by the Invention] However, in the field-effect transistor which used the organic semiconductor of the above-mentioned conventional configuration for the channel layer, it had the technical problem that are 10-1cm2/Vs extent from 10-2cm2/Vs, and it now needed a high drain electrical potential difference and high gate voltage at most if the drain current of a field-effect transistor tends to become small or the mobility of an organic-semiconductor thin film tends to acquire the same drain current since the value of mobility is low compared with an amorphous silicon.
[0046] Therefore, the combination of the organic semiconductor which realizes about the same high mobility as an amorphous silicon, and a gate insulating material is dramatically important.
[0047] the field-effect transistor structure which this invention solves the above-mentioned conventional trouble, and used the organic semiconductor for the channel layer -- mobility -- an amorphous silicon and an EQC -- or it aims at offering the field-effect transistor made into the value beyond it.
[0048]
[Means for Solving the Problem] In order to attain this object, this invention according to claim 1 is a field-effect transistor which has a gate electrode, a source electrode, a drain electrode, the channel section that consisted of organic-semiconductor ingredients, and the gate insulating layer which consisted of insulating polymers which have a cyano group.
[0049] And it is suitable for this organic-semiconductor ingredient to use a multi-conjugation organic compound including at least seven pi electron conjugated bonds which can say that pi conjugated system spread, and the compound shown by either of (** 21) from the following chemical formulas (** 16) may be used.
[0050]
[Formula 16]



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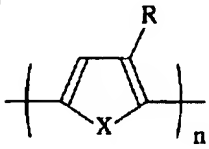
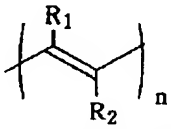
R_1，R_2はH，アルキル基、アリール基、ハロゲン
nは正の整数

[0051]
[Formula 17]



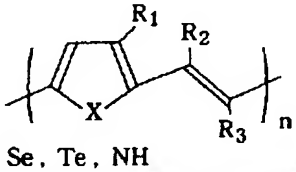
ただし、XはS，Se，Te，NH
RはH，アルキル基、アリール基、ハロゲン
nは正の整数

[0052]
[Formula 18]



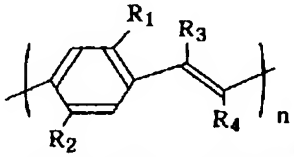
ただし、R_1，R_2はH，アルキル基、アリール基、ハロゲン
nは正の整数

[0053]
[Formula 19]



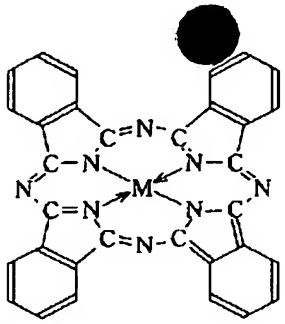
ただし、XはS，Se，Te，NH
R_1，R_2，R_3はH，アルキル基、アリール基、ハロゲン
nは正の整数

[0054]
[Formula 20]



ただし、R_1，R_2，R_3，R_4はH，アルキル基、アリール基、ハロゲン
nは正の整数

[0055]
[Formula 21]



ただし、Mは2価の金属

[0056] Furthermore, an organic-semiconductor ingredient may be the compound with which the pi electron conjugated system shown with the following chemical formulas (** 22) spread.

[0057]

[Formula 22]

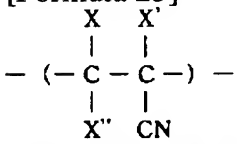
$R-(C_4H_2S)_n-R'$

ただしR，R'はH，アルキル基、ハロゲン、フェニル基

[0058] On the other hand, the compound shown by either of (** 26) from the following chemical formulas (** 23) may be used for the insulating polymer which has a cyano group.

[0059]

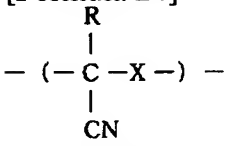
[Formula 23]



ただしX，X'，X''はH，アルキル基、フェニル基、ハロゲン

[0060]

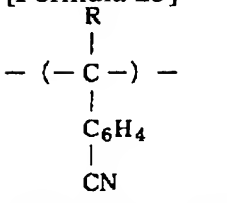
[Formula 24]



ただしXはO，S，S_e，CH_2，$-C_6H_4-$
RはH，アルキル基、ハロゲン、フェニル基

[0061]

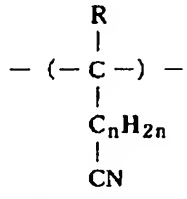
[Formula 25]



ただしRはH，アルキル基、ハロゲン、フェニル基

[0062]

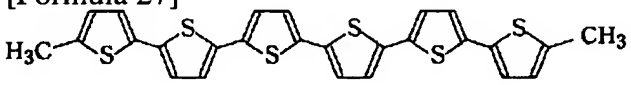
[Formula 26]



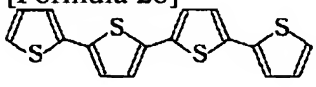
ただしRはH，アルキル基、ハロゲン、フェニル基
nは正の整数

[0063] And although the insulating polymer which has a cyano group has a good polymer with the high consistency of the cyano group in it, a polyacrylonitrile (PAN, a CAS registration number = 147237-94-3) is especially effective. This polyacrylonitrile is a polymer with the structure expression of (CH2CHCN).
[0064] Furthermore, although the concrete component configuration which can apply the above insulating polymer and organic-semiconductor ingredient is bipolar membrane which consists of an insulating polymer in which a gate insulating layer has silicon oxide and a cyano group and it is the thing of a configuration of that an insulating polymer with a cyano group touches the channel section, it is the configuration which has the channel section not only on this but on a gate insulating layer, the configuration which has a gate insulating layer and a gate electrode on the channel section, and application is possible.
[0065] Other ingredients are usable, if the insulating polymer which has the cyano group used for the organic material used for the channel section, of course or an insulating layer is not restricted to the above-mentioned thing but has the same function.
[0066] For example, as for an organic material, oligo thiophenes, the poly thiophenes, polypyrrole, Pori aniline, polyacethylenes, poly thienylene vinylenes, polyphenylene vinylenes and phthalocyanines, various hole transport ingredients, etc. are raised.
[0067]
[Function] The mobility of the organic semiconductor of a channel improves remarkably by using a polymer with a cyano group for a gate insulating layer, and a drain current increases.
[0068] For example, if the combination of the oligo thiophene which permuted by the gate insulating layer by the polyacrylonitrile, and permuted both ends by the channel section by the methyl group or the ethyl group is used, the high mobility of 4cm2/Vs will be obtained at the maximum, and this value belongs to the highest category as mobility of an organic-semiconductor thin film.
[0069] Furthermore, also when the bipolar membrane of a polyacrylonitrile / SiO2 grade is used as a gate insulating layer, mobility improves compared with the case on SiO2.
[0070] Moreover, even if a gate insulating layer is polyacrylonitrile independent and it is a polyacrylonitrile / bipolar membrane of SiO2 if the organic semiconductor touches the polyacrylonitrile since the contribution from from near the interface with the gate insulator of a channel is large, comparable mobility improves.
[0071] Because, since the current which flows the part of an interface with a gate insulating layer among the channel sections which tie a source electrode and a drain electrode is dominant, it is because mobility is influenced according to the class of gate insulating layer which is in contact with the channel.
[0072] In addition, the cyano group of the improvement in the mobility of the organic semiconductor by using a ** polymer is also effective over the organic semiconductor at large on which pi conjugated system spread.
[0073] Furthermore, in such a case, certainly high mobility is obtained that the class of organic semiconductor which can be used from the relation of an energy level is restricted in many cases so that it may set in the target component structure, for example, light emitting diode.
[0074]
[Example] An outline is explained before starting explanation of the concrete example of this invention.
[0075] First, although the typical field-effect transistor structure where the combination of the organic-semiconductor ingredient used for the channel section concerning this invention and the polymer ingredient which has the cyano group used for a gate insulating layer is applied is structure shown in drawing 1 , it is applicable also to the structure shown in drawing 4 from drawing 2 , of course.
[0076] Also in any, it has such structures in contact with the organic-semiconductor layer of the channel section, using the insulating polymer which has a cyano group as a part of gate insulating layer or gate insulating layer.

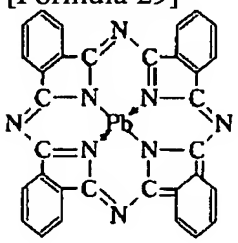
[0077] First, through the organic-semiconductor layer 16 which is the channel section which touched the gate insulating layer 13 which contains the insulating polymer which has a cyano group with the configuration of drawing 1 , the source electrode 14 and the drain electrode 15 are formed, the gate insulating layer 13 and silicon oxide 19 are compound-ized further, and it is the field-effect transistor using the silicon substrate or the metal substrate 18 as a gate [a substrate-cum-] electrode.
[0078] Moreover, it is the component structure which has the organic-semiconductor layer 26 in contact with the gate insulating layer 23 which the source electrode 24 and the drain electrode 25 are the gate insulating layer 23 containing the insulating polymer which has the gate electrode 22 on a substrate 21, and has a cyano group on it, and on it, and ties the source electrode 24 and the drain electrode 25 with the configuration of drawing 2 . Here, the conductive polymer which is in a metal condition as a gate electrode 22 for a metal electrode, an ITO electrode, and a high dope is used.
[0079] Moreover, with the configuration of drawing 3 , the silicon substrate and metal which being used as this gate [a substrate-cum-] electrode 37 at the point which is carrying out the configuration which replaced the substrate and gate electrode of drawing 2 with the gate [a substrate-cum-] electrode 37 unlike the configuration of drawing 2 doped to high concentration are used.
[0080] Moreover, with the configuration of drawing 4 , the gate electrode 42 is a component configuration above the organic-semiconductor layer 43, and it is inserted into the gate insulating layer 43 which consists of an insulating polymer with a substrate 41 and a cyano group, and the property of a component cannot be easily influenced of a controlled atmosphere, and since an organic semiconductor is not exposed, the organic-semiconductor layer 43 is having stable structure.
[0081] And with the configuration shown in drawing 3 from drawing 1 , after the gate insulation stratification, although what is necessary is just to form an organic-semiconductor layer by vacuum evaporationo etc., even if a gate insulating layer is formed in the upper part of an organic-semiconductor layer like drawing 4 , it can produce similarly, and improvement in mobility is shown.
[0082] Among this, the example which produced the field-effect transistor in each following example with the configuration of drawing 1 and drawing 4 using various organic semiconductors was shown, and mobility higher than the mobility of the organic semiconductor in the field-effect transistor of the structure which made the silicon oxide of the example of a comparison the gate insulating layer was checked. Of course, it is thought that high mobility is similarly presented with other component structures.
[0083] Moreover, as an insulating polymer with a cyano group, the polyacrylonitrile or the cyano ethyl pullulan was used typically.
[0084] Moreover, the used organic semiconductors are a dimethyl sexy thiophene (DMSxT), a quarter thiophene (QtT), and a lead phthalocyanine (PbPc:C32H16N8Pb, CAS registration number 15187-16-3), and those molecular structures are shown in order from the following (** 27) at (** 29).
[0085]
[Formula 27]



[0086]
[Formula 28]



[0087]
[Formula 29]



[0088] The hydrogen of the alpha position of both ends is the hexamer of the thiophene permuted by the methyl group, and recrystallizes the used dimethyl sexy thiophene with monochlorobenzene.
[0089] This dimethyl sexy thiophene has high mobility in about 5 figures as compared with a quarter thiophene according to the effectiveness which pi conjugated system permuted by the ******** or the methyl group.
[0090] In addition, composition of a dimethyl sexy thiophene was performed by the approach of a publication to advanced MATERIARUZU (S. Hotta, KWaragai, Adv.Mater.5 volume, 896 pages (1993)).
[0091] Moreover, a quarter thiophene is the tetramer of a thiophene and the hydrogen of the alpha position of both ends is a non-permuted thing.
[0092] Since these oligo thiophenes are gradually made by the Grignard reaction, it is single polymerization degree, and there are few impurities and a single crystal is easy to be obtained.
[0093] Therefore, there is no need for the dedope which is needed for a while by the field-effect transistor which used the organic semiconductor for the channel layer.
[0094] And the membraneous quality of the vacuum evaporationo film is also good, and a high order X-ray-analysis peak is accepted (journal OBU material chemistry magazine: indicate to S.Hotta, KWaragai, J.Mater.Chem., and 835 pages per volume (1991)).
[0095] therefore, the goodness of the membraneous quality of such a thin film -- ** -- it becomes and is easy to happen migration of the carrier between the molecules which suit -- the basis is carried out.
[0096] Moreover, since a commercial item contained many impurities, such as a phthalimide, the commercial item was used for it after the lead phthalocyanine carried out two sublimation purification.
[0097] Here, although measured about the lead phthalocyanine, since they do not change a lot even if the physical properties of a phthalocyanine complex change the class of central metal, generally its mobility improves similarly about a metal phthalocyanine divalent [other] or univalent and the phthalocyanine which does not contain a metal.
[0098] In addition, if the polymer which has a cyano group is used as a gate insulating layer, the reason whose mobility of a channel improves will be examined.
[0099] For example, the above-mentioned Garnier etc. is raised for reasons of the specific-inductive-capacity value of epsilon= 18.5 of a cyano ethyl pullulan (refer to Patent Publication Heisei No. 508745 [five to]). (with 10kHz)
[0100] However, with the field-effect transistor structure using the tantalic acid-ized film with the high specific inductive capacity shown in the below-mentioned example of a comparison (epsilon=24-25), it is mobility equivalent to the case on SiO2, and the activation energy of the mobility is also equivalent to the thing on SiO2.

[0101] Moreover, the specific inductive capacity of the polyacrylonitrile shown in the example of this invention it is epsilon= 4.5 (at 10kHz and 22 degrees C) (Eugen Neagu, Mihai Leanca, Rodica Neagu, and An.Stiint.Univ." -- aluminum.I.Cuza"Iasi and Sect. -- 1b and 20 (2) --) 133 - 8 pages 1974 -- a publication -- it is -- although it receives and the specific inductive capacity of at least 5 needs in the Patent Publication Heisei No. 508745 [five to] official report publication, the specific inductive capacity of a polyacrylonitrile is smaller than the value, and, moreover, has caused improvement in mobility.
[0102] Therefore, the ingredient of high specific inductive capacity which Garnier etc. describes will not necessarily have led to improvement in mobility.
[0103] About the reason whose mobility of a channel will improve if the polymer which has a cyano group is now used as a gate insulating layer, it has become clear that the operation of an electric dipole which a cyano group has and which carried out localization is dominant.
[0104] (Example 1) The 1st example of this invention is hereafter explained to a detail, making a drawing reference.
[0105] In this example, the field-effect transistor using the dimethyl sexy thiophene as an organic semiconductor was produced by using a polyacrylonitrile as a gate insulating-layer ingredient.
[0106] It has the configuration which specifically used the dimethyl sexy thiophene as the golden vacuum evaporationo film and an organic-semiconductor layer 46 respectively as a polyacrylonitrile, the source electrode 44, and a drain electrode 45 in the field-effect transistor of the configuration of drawing 4 as an insulating polymer which has a cyano group in the ITO film and the gate insulating layer 43 as a glass substrate

and a gate electrode 42 as a substrate 41.
[0107] The field-effect transistor which used the polyacrylonitrile for the gate insulating layer was produced as follows.
[0108] First, the washed glass substrate with the ITO (Indium Tin Oxcide) film (50ohm/**) was prepared, and on this, the spin coat of the 0.1g [/ml] dimethyl sulfoxide solution of a polyacrylonitrile (molecular weight 150,000, product made from Polyscience) was carried out by 1500rpm, and this spin coat film was dried using the dryer, and it considered as the gate insulating layer 43.
[0109] And on it, vacuum deposition of the gold was carried out and the source electrode 44 and the drain electrode 45 were formed respectively.
[0110] Moreover, each electrode of the source electrode 44, the drain electrode 45, and the gate electrode 42 was wired with a silver paste in the gold streak of 0.1mmphi, using the above-mentioned ITO film as a gate electrode 42.
[0111] Here, it is impedance analyzer Hewlett-Packard. Gate current was measured using 4194A, the gate capacitance between the source gates was broken by the electrode surface product, and it considered as the gate capacitance per unit area. And the typical value was 1 nF/cm2.
[0112] Then, the garbage was covered with aluminum foil etc., under the pressure of 2 - 4x10-6Torr, from the tungsten boat for sublimation metals separated from the vacuum evaporationo substrate 5cm, vacuum deposition of the dimethyl sexy thiophene 10mg was carried out by resistance heating, and it was used as the organic-semiconductor layer 46 so that it might be vapor-deposited by the channel part.
[0113] In this condition, the thickness near the core of a dimethyl sexy thiophene was set to 500nm.
[0114] And semi-conductor parameter analyzer 4145B of Hewlett-Packard, Keithley A 236 source major unit and programmable voltage source Keithley Each parameter of electric field effect TORAJISUTA of this example was measured using the system of measurement which controlled 617 with the personal computer.
[0115] Moreover, it can ask for mobility from following (several 2) which differentiated following (several 1) which gives the drain current ID of the linearity field of a field-effect transistor by VG to gate voltage.
[0116]
[Equation 1]

$$I_D = \mu C_0 W/L\{(V_G - V_T)V_D - V_D^2/2\}$$

[0117]
[Equation 2]

$$\Delta I_D/\Delta V_G = \mu C_0 V_D W/L$$

[0118] here -- mu -- for channel width and L, channel length and VG are [mobility and C0 / the gate capacitance per unit area, and W / a drain electrical potential difference and VT of gate voltage and VD] threshold electrical potential differences.
[0119] Moreover, it replaced with the dimethyl sexy thiophene, the field-effect transistor was similarly produced about the quarter thiophene and the lead phthalocyanine, and same measurement was performed.
[0120] At this time, the thing with a channel width of W= 0.01cm was produced by L= 2.4cm of channel length, and two kinds of things with a channel width of W= 0.02cm were produced by L= 0.6cm of channel length.
[0121] The operating characteristic of these field-effect transistors is shown in drawing 5 (a) - (c). All over drawing, each channel width W, channel length L, and the gate capacitance C0 per unit area were shown.
[0122] In these drawings, since the drain current is increasing when the gate voltage of minus is impressed, a dimethyl sexy thiophene, a quarter thiophene, and a lead phthalocyanine show that the semi-conductor property of p mold is shown.
[0123] And in the case of the field-effect transistor of the dimethyl sexy thiophene of drawing 5 (a), change of the drain current over gate voltage is the largest, and, moreover, the ratio of change of the drain current in VG=0V and VG=-11V is large.
[0124] As a result, the mobility of 1.3x10-4cm2/Vs was obtained by the dimethyl sexy thiophene by 2cm2/Vs (it is 4cm2/Vs at maximum), and was obtained by 1.4x10-5cm2/Vs and the lead phthalocyanine by the quarter thiophene.
[0125] These values have the large mobility of the dimethyl sexy thiophene on silicon oxide, a quarter thiophene, and a lead phthalocyanine single or more figures to being 10-2, 2x10-7, and 10-5cm2/Vs

respectively, and it turns out that the marked improvement in mobility is brought about.
[0126] As mentioned above, by using the polyacrylonitrile which is the insulating polymer which has a cyano group in a gate insulating layer in the field-effect transistor which used the organic semiconductor for the channel layer according to this example, the field-effect transistor which has mobility higher than what used silicon oxide for the gate insulating layer can be obtained, and it is thought that the improvement in the mobility by the polymer with this cyano group is effective in a wide range organic semiconductor.
[0127] Furthermore, in order not to dissolve a polyacrylonitrile in the usual organic solvent but to only dissolve in the solvent restricted [dimethylformamide / dimethyl sulfoxide,], it also has the advantage to which organic washing and lithography become possible after producing a polyacrylonitrile.
[0128] In addition, the mobility which made field-effect transistor structure in this way, and was measured is time. of It may differ from the mobility measured by the flight method.
[0129] Because, time of By the flight method, since a carrier is generated by optical exposure, it is unrelated to a generation of carriers where the absolute level of HOMO (highest occupied molecular orbital) of a molecule or LUMO (a minimum sky molecular orbital) is, and the energy difference of HOMO and LUMO is related to a generation of carriers.
[0130] It is because it is based on the applied voltage in the MIS (metal insulator semiconductor) structure of the organic semiconductor of a gate electrode, a gate insulating layer, and the channel section, so it is influenced by the relation of the energy level of a gate electrode, a gate insulating layer, and an organic semiconductor with field-effect transistor structure on the other hand.
[0131] For example, time of By the flight method, even when the anthracene single crystal which can usually be measured is used, if it is made field-effect transistor structure, measurement of mobility cannot be performed.
[0132] An anthracene does not have absorption in a visible region, but this has the large energy difference of HOMO-LUMO, and since the level of HOMO is in a deep level rather than the level of HOMO of tetracene, it twists a carrier with gate applied voltage with field-effect transistor structure for induction not to be carried out, so that transparently.
[0133] Thus, the mobility for which it asked by field-effect transistor measurement is time. offlight Although it may differ from the mobility for which it asked by law, the mobility for which it asked by this example is more practical than the mobility for which can set in the field-effect transistor structure actually used as a component, and it asked in the single crystal.
[0134] (Example 2) The 2nd example of this invention is explained hereafter, making a drawing reference.
[0135] This example explains the field-effect transistor which has the compound insulating layer which consists of a polyacrylonitrile layer shown in drawing 1 , and silicon film.
[0136] The field-effect transistor which specifically used the dimethyl sexy thiophene as a polyacrylonitrile and an organic-semiconductor layer 16 as a polymer layer 13 which has a cyano group was produced as follows.
[0137] First, cleavage of the silicon substrate 18 of n mold high concentration dope which the 1000A thermal oxidation film (silicon oxide) 19 attached is carried out to the magnitude which is easy to carry out a spin coat.
[0138] In addition, at this time, since the oxide film of the rear face made when growing up the thermal oxidation film was simple, the sandpaper removed, and the flow with the silicon substrate for taking out a gate electrode and a silver paste was secured.
[0139] next, the spin coat of the 0.1g [/ml] dimethyl sulfoxide solution of a polyacrylonitrile (molecular weight 150,000, product made from Polyscience) was boiled and carried out on silicon oxide by 1000 or 2000rpm.
[0140] The spin coat film was dried using the after [a spin coat] dryer, and it considered as the polymer layer 13 which has a cyano group.
[0141] Vacuum deposition of the golden electrode used as the source electrode 14 and a drain electrode 15 on it is carried out (channel length of L= 2.4cm, channel width of W= 0.01cm).
[0142] And after vapor-depositing a golden electrode, cleavage of the silicon substrate 18 was carried out, it fixed on the non-illustrated printed circuit board, and wiring of a gold streak was carried out using the silver paste, and the printed circuit board and the gold streak (phi0.1mm) were fixed with the epoxy adhesive so that the force might be applied to a gold streak and it might not peel.
[0143] In addition, the thin film 13 of a polyacrylonitrile separates the spin coat film 13 of a polyacrylonitrile beforehand with the cutter knife, after applying and hardening an epoxy adhesive to the end face of the spin coat film 13 of a polyacrylonitrile, and a silicon substrate 18, since adhesion with silicon oxide 19 tends to peel

easily well in advance of cleavage at this time.
[0144] Moreover, it is Hewlett here. Packard 4194A impedance/gain phase Gate capacitance C0 was computed by having measured the parameter by analyzer and having broken the capacity of the capacitor of the equal circuit of good juxtaposition of coincidence by low frequency by the electrode surface product, and the gate capacitance C0 per the unit area was shown in the graph of a measurement result.
[0145] Then, it left the channel periphery and the mask was carried out with aluminum foil, vacuum deposition of the dimethyl sexy thiophene 10mg was carried out in the distance of the boat for tungsten sublimation metals to 5cm under the pressure of 2x10-6 - 4x10-6Torr, and the oligo thiophene film which is the organic-semiconductor layer 16 of about 500nm of thickness was formed.
[0146] And it is as being shown in drawing 6 , and the large mobility of 2/Vs was obtained 1cm by the result of having measured the field-effect transistor property like the example 1.
[0147] In addition, the structure which used the insulating layer as the bipolar membrane of a polymer insulating layer and silicon oxide has the following advantages.
[0148] Since the bipolar membrane of a polymer layer / silicon oxide film tends to secure the insulation of the gate, it can make thickness of a polymer layer thinner than a polymer independent insulating layer.
[0149] For this reason, this bipolar membrane tends to secure the electric capacity of the gate per unit area from a polymer independent case, and a big drain current is acquired also in the combination of the same mobility, channel length, and channel width.
[0150] (Example 3) The 3rd example of this invention is explained hereafter, making a drawing reference.
[0151] At this example, a cyano ethyl pullulan is used for a gate insulating layer, and it is the thing using the lead phthalocyanine as an organic semiconductor, and is the same as that of the making process and basic target of an example 1.
[0152] In the configuration of drawing 4 , it specifically supposes that it is an insulating polymer 43 which has the ITO film and a cyano group as a glass substrate and a gate electrode 42 as a substrate 41, and a lead phthalocyanine is used as the golden vacuum evaporationo film and an organic-semiconductor layer 46 as a cyano ethyl pullulan, the source electrode 44, and a drain electrode 45.
[0153] The glass substrate with the ITO film used as the gate electrode 42 (50ohm/**) was washed and prepared, and the spin coat of the volume mixed solvent solutions, such as a 0.2g [/ml] acetonitrile, dimethylformamide, etc. of CYEPL (the product made from the Shin-etsu chemistry, trade name cyano resin CR-S), was carried out by 1000rpm on this.
[0154] The spin coat film was dried using the after [a spin coat] dryer, and it considered as the gate insulating layer 43.
[0155] And on it, vacuum deposition of the golden electrode used as the source electrode 44 and a drain electrode 45 was carried out, and it was formed.
[0156] Here, it is gate capacitance Impedance analyzer Hewlett-Packard It measured using 4194A.
[0157] Then, the garbage was covered with aluminum foil etc. and vacuum deposition of the lead phthalocyanine was carried out by resistance heating from the tungsten boat for sublimation metals under the 2 - 4x10-6Torr pressure.
[0158] Here, they could be L= 2.4cm of channel length, 0.6cm, the channel width of W= 0.01cm, or 0.02cm.
[0159] Subsequently, the field-effect transistor was produced like [thiophene / a dimethyl sexy thiophene and / quarter] the case of a lead phthalocyanine, and each parameter was measured like the example 1.
[0160] The measurement result of ****** was as being shown in drawing 7 (a) - (c), and was [in the dimethyl sexy thiophene] 3.2x10-3cm2/Vs in 3x10-5cm2/Vs and a lead phthalocyanine at 3cm2/Vs, and a quarter thiophene.
[0161] Therefore, also in this example, when the cyano ethyl pullulan which has a cyano group was used for the gate insulating layer, the field-effect transistor whose mobility of an organic semiconductor improved by things was able to be obtained.
[0162] (Example 4) The 4th example of this invention is explained hereafter, making a drawing reference.
[0163] In this example, the cascade screen of a cyano ethyl pullulan and silicon oxide was used as a gate insulating layer.
[0164] Specifically in drawing 1 , it is the same as that of the making process and basic target of an example 2 as an insulating polymer layer 13 which has a cyano group, using a dimethyl sexy thiophene as a cyano ethyl

pullulan and an organic-semiconductor layer 16.
[0165] Here, in order to secure sufficient insulation of a gate insulating layer, on the thermal oxidation film on the silicon substrate 18 of n mold high concentration dope (silicon oxide : 104.6nm in thickness), the spin coat of the CYEPL solution of volume mixed solvents, such as an acetonitrile, was carried out to dimethylformamide (2g / 10ml) by 1000rpm, and the spin coat film was dried with the dryer and it considered as the insulating layer 13.
[0166] In this example, the insulating layer 13 which is the CYEPL spin coat film has good adhesion with silicon oxide.
[0167] Also in this example, each parameter of a field-effect transistor is measured similarly, and the result is shown in drawing 8 . And the called-for mobility is 9x10-2cm2/Vs, and had the high value.
[0168] In addition, the measurement result of the mobility of the above example was summarized in the following (table 1).
[0169]
[A table 1]

ゲート絶縁層	ジメチルセクシチオフェンの移動度 (cm^2/Vs)	クォータチオフェンの移動度 (cm^2/Vs)	鉛フタロシアニンの移動度 (cm^2/Vs)
SiO_2	10^{-2}	2×10^{-7}	10^{-5}
ポリアクリロニトリル	2	1.4×10^{-5}	1.3×10^{-4}
シアノエチルプルラン	3	3×10^{-5}	3.2×10^{-3}
ポリアクリロニトリル/SiO_2	1	未測定	未測定
シアノエチルプルラン/SiO_2	7×10^{-2}	未測定	未測定

[0170] (Example 1 of a comparison) In this example of a comparison, the field-effect transistor which used silicon oxide for the gate insulating layer was produced as follows. On n mold silicon substrate (rho= 0.01-ohmcm), the oxide film (270nm in thickness) was formed, on it, chromium (15nm in thickness) and gold (150nm in thickness) were vapor-deposited serially, and the source and a drain electrode were formed.
[0171] Here, it considered as the channel length of L= 4 micrometers, and the channel width of W= 1.5mm, and was gate capacitance C0=12 nF/cm2.
[0172] Subsequently, after mounting a wafer on an after [cleavage] ceramic package, it wired by the ball bonder, and vacuum deposition of the dimethyl sexy thiophene was carried out by resistance heating from the tungsten boat for sublimation metals under the 2 - 4x10-6Torr pressure after that.
[0173] The typical thickness near the core when setting distance of a boat and a vacuum evaporationo substrate to about 5cm, and flying 10mg of sources of vacuum evaporationo at this time, was 500nm.
[0174] Subsequently, when a quarter thiophene and a lead phthalocyanine were used for an organic semiconductor, even if it attached, the field-effect transistor was produced similarly.
[0175] Moreover, measurement of each parameter of a field-effect transistor was performed like the above-mentioned example.
[0176] Although only the measurement result in a lead phthalocyanine was shown in drawing 9 , the result was as low at 2x10-7cm2/Vs and a lead phthalocyanine a value as 10-5cm2/Vs in 10-2cm2/Vs and a quarter thiophene at the dimethyl sexy thiophene, as shown in (a table 1).
[0177] (Example 2 of a comparison) Further, in order [with this invention] to compare, the field-effect transistor of a gate insulating layer which consists of 2O5/SiO2 of Ta bipolar membrane was produced using the tantalic acid-ized film Ta 2O5 which has specific inductive capacity (epsilon=24-25) higher than CYEPL.
[0178] Here, in order to secure sufficient insulation of a gate insulating layer, on the thermal oxidation film (104.6nm in thickness) of the silicon on n mold silicon substrate, the tantalic acid-ized film was produced by the spatter in thickness of 201.0nm, and the source and a drain electrode were produced on it (channel length of L= 0.1mm, channel width of W= 24mm).
[0179] Moreover, the electric capacity per unit area of Ta2O5/SiO2 bipolar membrane (16.7 nF/cm2) was well in agreement with the value calculated as serial electric capacity of the electric capacity of the tantalic acid-ized film, and the electric capacity of silicon oxide.

[0180] And using a dimethyl KUINKE thiophene (pentamer of a thiophene which permuted the hydrogen of the alpha position of both ends by the methyl group) as an organic semiconductor of a channel layer, the film was produced with vacuum deposition from the tungsten boat, and the field-effect transistor was produced.
[0181] Measurement of each parameter of a field-effect transistor is the same as that of the above-mentioned example. Although the result was shown in drawing 10 , the mobility on Ta2O5 / SiO2 bipolar membrane is 1.8x10-3cm2/Vs, and became a case on silicon oxide, and a value without great difference.
[0182] Moreover, the measured value of activation energy was also set to the same 0.17eV as the case on silicon oxide.
[0183] Thus, the fact that the mobility of an oligo thiophene is not influenced even if it uses the tantalic acid-ized film of a high dielectric constant shows that the factor of the improvement in mobility is not the specific inductive capacity of a gate insulating layer.
[0184] When the artificer considered this cause, it became clear that the improvement in this mobility has the dominant operation of an electric dipole which a cyano group has and which carried out localization.
[0185] Moreover, even if it distributes the organic compound which has a cyano group in other polymers, it is expectable that the same effectiveness is shown by work of the electric dipole contained in it.
[0186]
[Effect of the Invention] As mentioned above, in the field-effect transistor which used the organic semiconductor for the channel section, by using the insulating polymer which has a cyano group in a gate insulating layer, the mobility in an organic-semiconductor thin film can be raised, and a drain current can be increased as the result in this invention.
[0187] furthermore, the combination of a dimethyl sexy thiophene and a polyacrylonitrile -- max -- 4cm2 / Vs thing -- high mobility is also realizable.
[0188] therefore, the field-effect transistor structure which used the organic semiconductor for the channel layer -- setting -- an amorphous silicon and an EQC -- or an aperture and its effectiveness are large in the way which can say that the mobility of the carrier beyond it was realizable, and can use various organic semiconductors for a field-effect transistor.

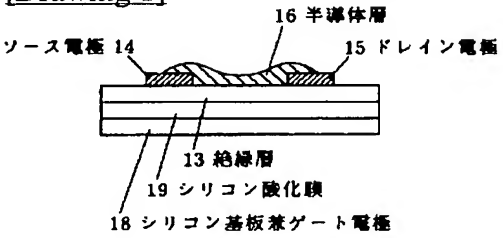
[Translation done.]

* NOTICES *

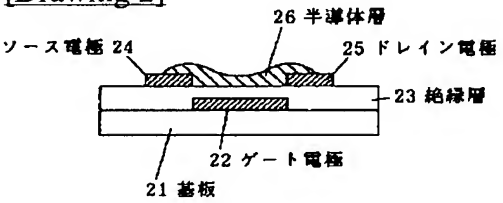
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

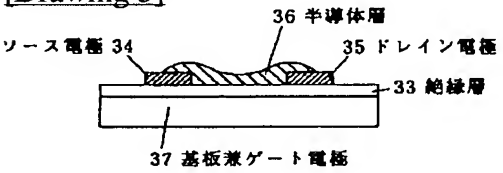
[Drawing 1]



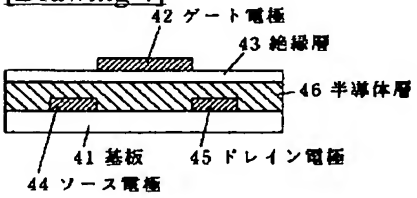
[Drawing 2]



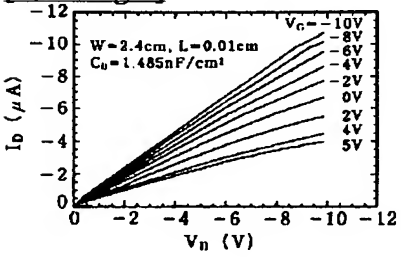
[Drawing 3]



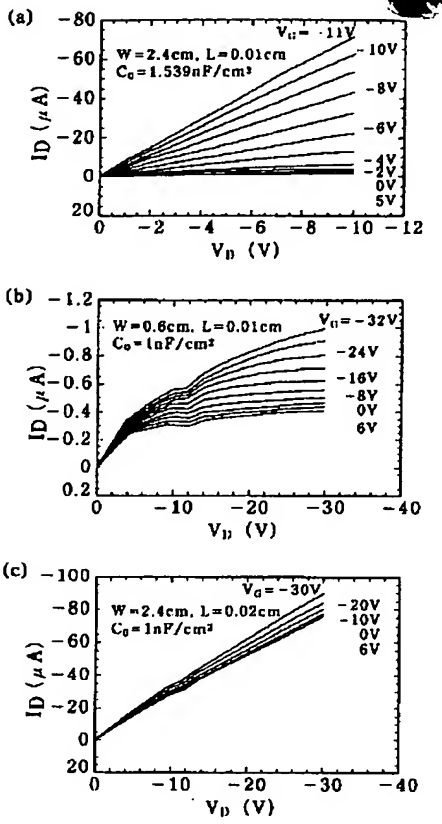
[Drawing 4]



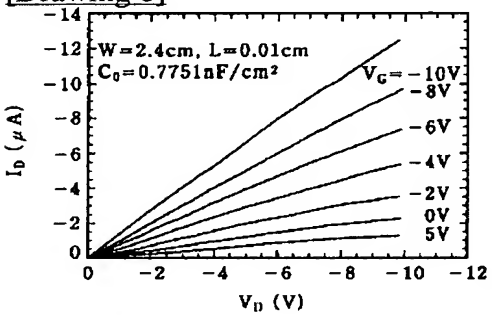
[Drawing 8]



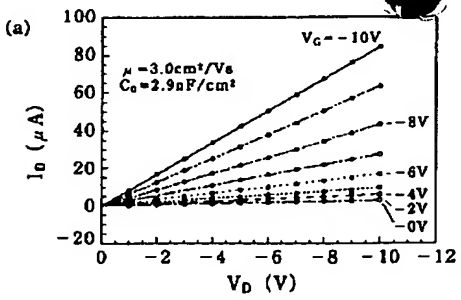
[Drawing 5]

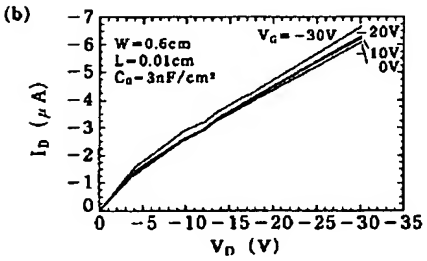


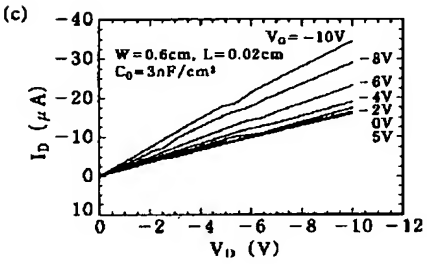
[Drawing 6]



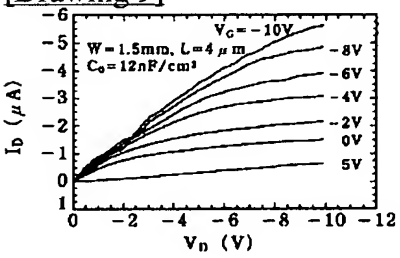
[Drawing 7]



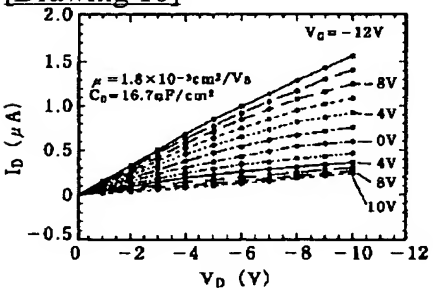




[Drawing 9]



[Drawing 10]



[Translation done.]